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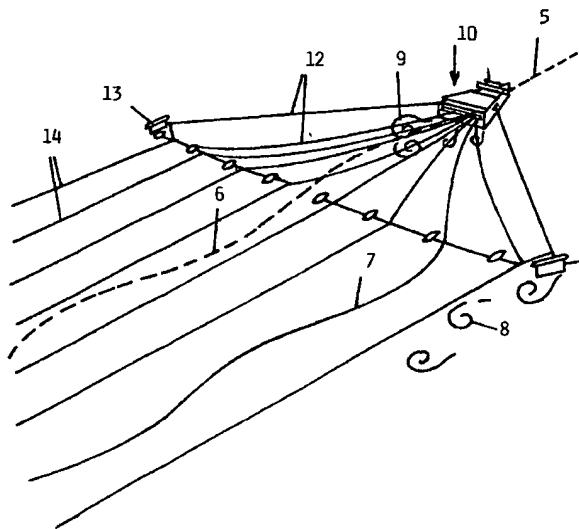
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- (71) Applicant (for all designated States except US): **PETROLEUM GEO-SERVICES AS** [NO/NO]; Strandveien 5, N-1324 Oslo (NO).
- (72) Inventors; and
- (75) Inventors/Applicants (for US only): **PEDERSEN, Egil** [NO/NO]; Weidemanns vei 7B, N-7014 Trondheim (NO). **RØNNINGEN, Rolf** [NO/US]; 17106 Crown Meadow Court, Houston, TX 77095 (US). **NALEY, Svein, J.** [NO/NO]; Neuberggt. 19, N-0368 Oslo (NO).
- (74) Agent: **ABC-PATENT, SIVILING. ROLF CHR. B. LARSEN A.S.**; Postboks 6150 Etterstad, Brynsveien 5, N-0602 Oslo (NO).
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[Continued on next page]

(54) Title: **SYSTEM FOR CONTROLLING STREAMERS**



(57) Abstract: System for controlling cables and streamers in a seismic tow arrangement comprising at least one deflector (13) connected to one side of a tow vessel (10) via at least one wire (12), leading or the like, wherein the deflector is located in a position at a distance perpendicularly to the direction of movement (5) of the tow vessel, the vessel being equipped with a navigation system for measuring the position of the vessel. The system is characterised by comprising a command unit and a number of control units, where the control units are located on at least some of the streamers and are adapted to measure and report about their positions, that the command unit comprises means for receiving the position information from each individual control unit and calculation of possible deviations from predetermined positions, and that the system comprises means for changing the position of the streamers for re-establishing the positions of the control units.

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*For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

## SYSTEM FOR CONTROLLING STREAMERS

This invention relates to a system and a method for controlling seismic towed arrangements with a towing vessel equipped with a navigation system for measuring the position of the vessel.

In seismic prospection at sea there is most often employed a number of seismic cables being towed behind a vessel. The prospecting of the geological formations in the seabed is carried out by having one or more acoustic sources emitting sound waves downwards into the seabed where they are reflected at the transition between different types of formations. The reflected signals are received by sensors mounted in the seismic cables or streamers. The cables are towed along a selected path in order to investigate a given area. The movements of the vessel and the seismic tow arrangement must be controlled accurately in order to secure coverage of the desired areas.

Exact control of the positions of the vessel and the towed arrangement is particularly important when the same reflection point shall be investigated several times, in order to improve the measurements. This can be done by controlling the time between the emitted acoustic signals in relation to the distance between the sensors along each streamer, and the speed of the vessel, so that the next signal is reflected from the reflection point upwards to a subsequent sensor in the direction of movement along the same streamer.

In order to secure accurate measurements it has been common to monitor the position of the vessel by means of existing navigation systems, for correcting the position. It has been found, however, that it is difficult to obtain a sufficient degree of accuracy, among other things, due to the dimensions and the large inertia of the vessels. Various systems have also been employed to compensate for errors, for example by means of signal processing, oversampling or by controlling the deflectors which pull the seismic streamers laterally out from the vessel; this increases the complexity of the system, in that control signals and power,

inter alia, must be conveyed from the vessel to the deflectors.

US patent 4.781.140 relates to a system for compensation of the orientation of the vessel in relation to the direction of movement. The seismic streamers are connected to rigid beams the orientation of which, with respect to the vessel, is changed by means of wires when for example the vessel is directed against the wind or the stream. This however, does not involve any possibility of compensating for deviations in the position of the vessel in relation to an intended course.

Other examples of devices and systems for keeping a seismic streamer in a correct position are found in US 4.711.194, US 4.222.340, US 3.961303 and US 3.943.483 as well as US 5.790.472.

The towed seismic arrangement usually comprises a number of control units located along each streamer, for example in order to keep the streamer at a certain depth or position. A main problem with the known solutions for controlling seismic streamers is that the control of the control units being mounted along each cable is not coordinated. This means that the control units adjust the streamer position independently of one another, and this can have the consequence that the units do not react in an optimal manner in terms of counteracting a position disturbance in the streamer system. Such disturbances can for example be caused by an unstable path control of the towing vessel, and turbulence from the towed equipment and the towing vessel.

The present invention has its main object to provide a control system for seismic streamers, which coordinates the effect of the control units so that the position regulation is at an optimum at all times, and also with respect to energy consumption. It is also an object of this invention to provide a system that can employ existing control units, so that large and expensive reconstructions are avoided.

These objects are obtained by means of a system as stated in the attached independent claim.

The invention will be described more closely below with reference to the accompanying drawings, illustrating the invention by way of examples.

5 Figure 1 illustrates the movements of a seismic prospecting vessel according to prior art.

Figure 2 illustrates the movements of a seismic prospecting vessel according to the invention.

10 Figure 3 shows the control system for coordinated control of the control units according to the invention, and

Figure 4 schematically illustrates the input of information to the control unit.

15 Figure 1 illustrates how a seismic prospecting vessel 1 according to the prior art can move under the influence of various wind and stream conditions. The vessel 1 is connected to a seismic tow arrangement 2,3,4 comprising tow cables 2 and deflectors 3 which pull out the arrangement laterally in relation to the towing direction, and seismic streamers 4 comprising sensors, such as hydrophones. 20 Besides, the towed arrangements comprises seismic sources being connected directly to the vessel 1.

In figure 1 the vessel shall follow a predetermined course, but because of wind and stream conditions, the real movement will deviate there from. The control system that 25 compensates for the deviations will normally result in an oscillating movement about the predetermined course. The seismic towed arrangement, being connected to the vessel with towing cables, lead-ins or the like 2 having fixed lengths, will follow the movements of the vessel.

30 In figure 2 the vessel 10 (compare 1, fig. 1) shall follow a predetermined course 5, but because of, inter alia, environmental disturbances (wind, stream and wave conditions) the true movements will usually deviate there from. The control system of the vessel that compensates for 35 the environmental effect or influence, usually will result in an oscillating movement about the predetermined course, which is illustrated by the true path 6 of the vessel. The seismic towed arrangement will be influenced by an unstable

path control both in the horizontal and depth plane 7.  
Turbulence 8 from the deflectors and the propeller wake and  
turbulence 9 from the towing vessel will also give rise to  
position disturbances of the seismic streamers.

5           In figure 2 the vessel 10 according to the invention,  
is provided with devices changing the length of the towing  
cable in response to changes in the position of the vessel  
in relation to the predetermined course 6. This solution is  
more closely described in international patent application  
10 No. PCT/NO00/00244, and will not be described in detail  
here, often in combination with a change of the towing cable  
in order to maintain a correct position in relation also to  
the sailing direction of the vessel.

Other solutions for changing the horizontal position  
15 can be per se well known adjustable deflectors which can  
regulate the distance to the vessel by changing the lift  
capacity. An example of such an active deflector is shown in  
international patent application No. PCT/NO97/00302.

In a corresponding manner the depth can be adjusted by  
20 means of depth controllers as known per se, for example as  
described in international patent application No.  
PCT/NO98/00187.

In a usual way vessel 10 is equipped with navigation  
systems, for example GPS (Global Positioning System), that  
25 measures the deviations in relation to the predetermined  
course, and which can be used to compensate for deviation in  
the movements of the vessel. Since it is substantially  
easier and quicker to pull in or pay out the towing wire,  
than it is to adjust the position of the vessel, the  
30 position of the towed arrangement can be changed more  
quickly than the position of the vessel. Thus, the seismic  
towed arrangement can maintain a more stable course than the  
towing vessel 10 itself.

For exact control of the position of the seismic towed  
35 arrangement, the vessel is provided with devices for  
measuring the positions of one or more parts of the towed  
arrangement, for example the deflectors, in relation to the  
vessel. Thereby, a measured deviation of the position of the

vessel can be compensated for directly by paying out or pulling in a sufficient amount of cable, and/or by adjusting the lift capacity of the deflectors, until the deflector has a correct position both globally and with respect to the vessel 10. In a corresponding manner regulation of depth controllers will adjust the depth deviation of the streamer.

Compensation for the transverse deviation by changing the cable length only, can lead to a relative displacement of the deflectors in the direction of movement, thus giving rise to changes in the positions of the seismic streamers mutually. This can constitute a problem in data acquisition, and can therefore be compensated for in other ways, for example by regulating the length of the deployed seismic streamers or by employing active deflectors which increase the lifting capacity so that the variation of the deployed streamer length will be smaller, whereas the lifting effect of the deflectors is used to maintain a more regular position in relation to the direction of the movement of tow vessel.

In addition, for obtaining an increased accuracy, the heave, roll and pitch movement of the vessel can be measured and compensated for according to the invention.

In the preferred embodiment of the invention the system comprises a deflector 13 at either side of the vessel 10, whereby the adjustment comprises at least the tow cables 12 to the deflectors, but can also comprise the other wires, streamers or lead-ins. This will also involve a possibility of adjusting the seismic streamers' position in the direction of movement to compensate for the displacement that otherwise would be a consequence of the length change of the tow cable 12 to the deflector 13. Figure 2 shows a tow situation where the seismic streamers 14 are connected to one another and to the deflectors with cables which thus results in the desired spacing of the streamers. It is of course possible to subdivide the towed arrangement into several parts or sections, each being provided with one or more deflectors, and where the position of each of these parts or sections can be adjusted in order to maintain the

seismic towed arrangement at a predetermined course.

Figure 3 shows the control system for coordinated control of the control units 33 according to the invention. The control system comprises a command unit 31 which  
5 monitors each individual control unit 33 for one or more seismic streamers 14. The control units can measure a number of parameters, such as power or effect, depth or position, in a manner known per se for each of these. The control units can be located in the leading ends of the streamers,  
10 as is common today, or along each streamer, and can consist of conventional depth controllers "birds" with measuring devices, or they can be of a more sophisticated kind.

The command unit 31 comprises calculating means for calculating of optimum power or effect (control power) for  
15 each individual control unit in relation to a predefined position and known parameters for the control unit 33. This information is processed and possible signals regarding a change of the positions of the streamer and the control units, are sent to one or more of the above means or  
20 devices.

The signal transfer to and from the command unit can be via electrical or optical conductors 34 in cables or lead-ins, or can be conveyed via radio or acoustic signals.

With reference to figure 4 the command unit 31 receives  
25 signals from the control units 33 based on measurement methods known per se, in order to maintain depth, effect or power, and position. For example can depth be measured by pressure measurement, power or effect by means of measurements of fin or wing angle of a sensor, and position  
30 by means of a compass or via acoustic measurement methods in order to determine relative positions between the cables or streamers. Additionally also position measurements and possibly other measurements can be performed from instruments 34 mounted in the streamer itself.

35 Besides, as mentioned above, the tow vessel comprises navigation aids 32 being connected to the command unit 31 in order to supply information thereto, for example regarding global position (via satellite navigation systems or the



like), movement, gyro and the like, so that the positions of the streamers with respect to the movements of the vessel and the geological formations to be investigated, can be controlled.

5           The actual control can take place by having the planned movement of the seismic tow arrangement in the form of position, the depth of the streamers and so forth stored in the command unit, and information regarding the real positions thereof being calculated on the basis of the  
10       global position of the vessel and the measurements from the individual control units. Deviations from the desired positions are recorded and the different control devices, as for example active deflectors, winches, depth controllers and the like, are activated individually in relation to the  
15       desired positions of the various parts or sections of the tow arrangement.

          Although the figures of drawings show a symmetrical tow arrangement, it is of course possible to take advantage of the invention in the case of asymmetric tow arrangements,  
20       for example in the case of several vessels together forming a seismic tow arrangement. A solution wherein the whole tow arrangement is located at one side of the vessel, can also be contemplated, for example in prospecting near land, where the vessel must be kept at a certain distance from the  
25       shore.

          Although the invention is primarily described here for the purpose of compensating for drift with respect to a predetermined course, it is obvious that it can also be employed for keeping the seismic tow arrangement along a  
30       predetermined path, whereas the vessel for example makes manoeuvres in order to avoid obstacles. For example there may be the case of a river where the possible sailing path is not necessarily straight.

## Claims

1. System for controlling cables and streamers in a seismic tow arrangement comprising at least one deflector (13) connected to one side of a tow vessel (10) through at least one wire (12), lead-in or the like, wherein the deflector is located at a position with a distance perpendicularly of the direction of movement (5) of the tow vessel, the vessel being equipped with a navigation system (32) for measuring the position of the vessel, characterised by comprising a command unit (31) and a number of control units (33), the control units being located on at least some of the streamers (14) and being adapted to measure and report regarding their positions,

that the command unit (31) comprises means for receiving position information from each individual control unit (31) and calculation of possible deviations from predetermined positions,

and that the system comprises means for changing the position of the streamers in order to restore the positions of the control unit.

2. System according to claim 1,  
c h a r a c t e r i s e d i n that the position information from at least one control unit (33) comprises horizontal and vertical position.

3. System according to claim 1 or 2,  
c h a r a c t e r i s e d i n that the command unit (31) comprises means for measuring the relative position of the deflector (13) with respect to the vessel (10), and that the compensation comprises control of the global position of the deflector on the background of the position of the tow vessel and the relative position of the deflector with respect thereto.

4. System according to claim 1, 2 or 3,  
c h a r a c t e r i s e d i n that at least one control

device (33) comprises a depth measuring instrument and that the system comprises at least one depth controller connected to the depth measuring instrument, for adjusting the vertical position thereof.

5. System according to anyone of claims 1-4, characterised in that the tow wire (12) is connected to the tow vessel (10) via control devices, for example a winch, adapted to vary the wire length from the tow vessel to the deflector (13) and that the control devices are connected to the calculating means for adjusting of the wire length on the basis of said deviation in the position of the tow vessel, in order to counteract corresponding deviations in the movement of the deflector.

6. System according to anyone of claims 1-5, characterised in that the command unit (31) also comprises means as known per se for measuring deviations in the orientation of the vessel, for example roll, heave and pitch.

7. System according to anyone of the claims 1-6, characterised in comprising means for adjusting the lifting capacity of the deflector (13) for adjusting the position of the deflector.

8. System according to anyone of the claims 1-7, characterised in the streamer (14) comprises means (33) for measurement of position, and transfer thereof to the command unit.

9. System according to anyone of the claims 1-8, characterised in that the control units (33) are located in association with selected points at the streamers (14), the deflectors (13) and the depth controllers, for measuring selected variables such as effect or power, position and depth at each individual control unit.

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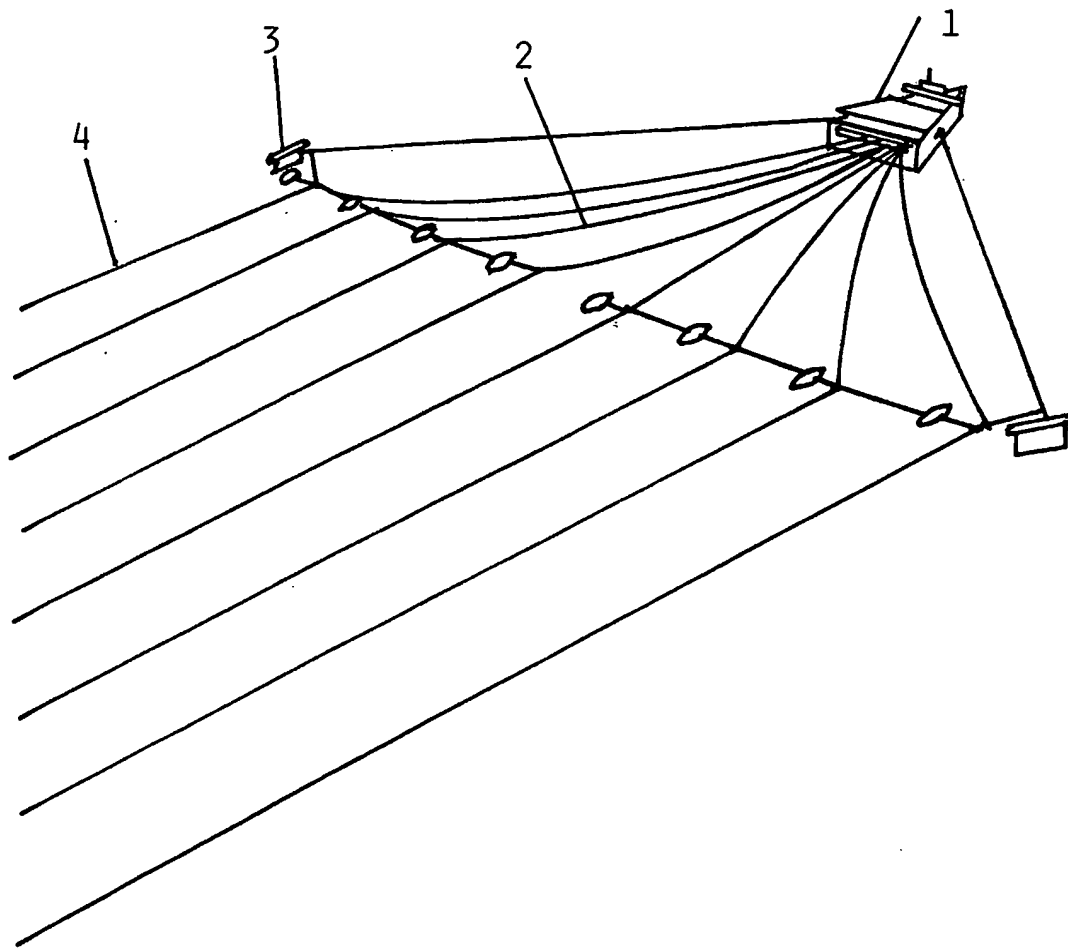


FIG. 1

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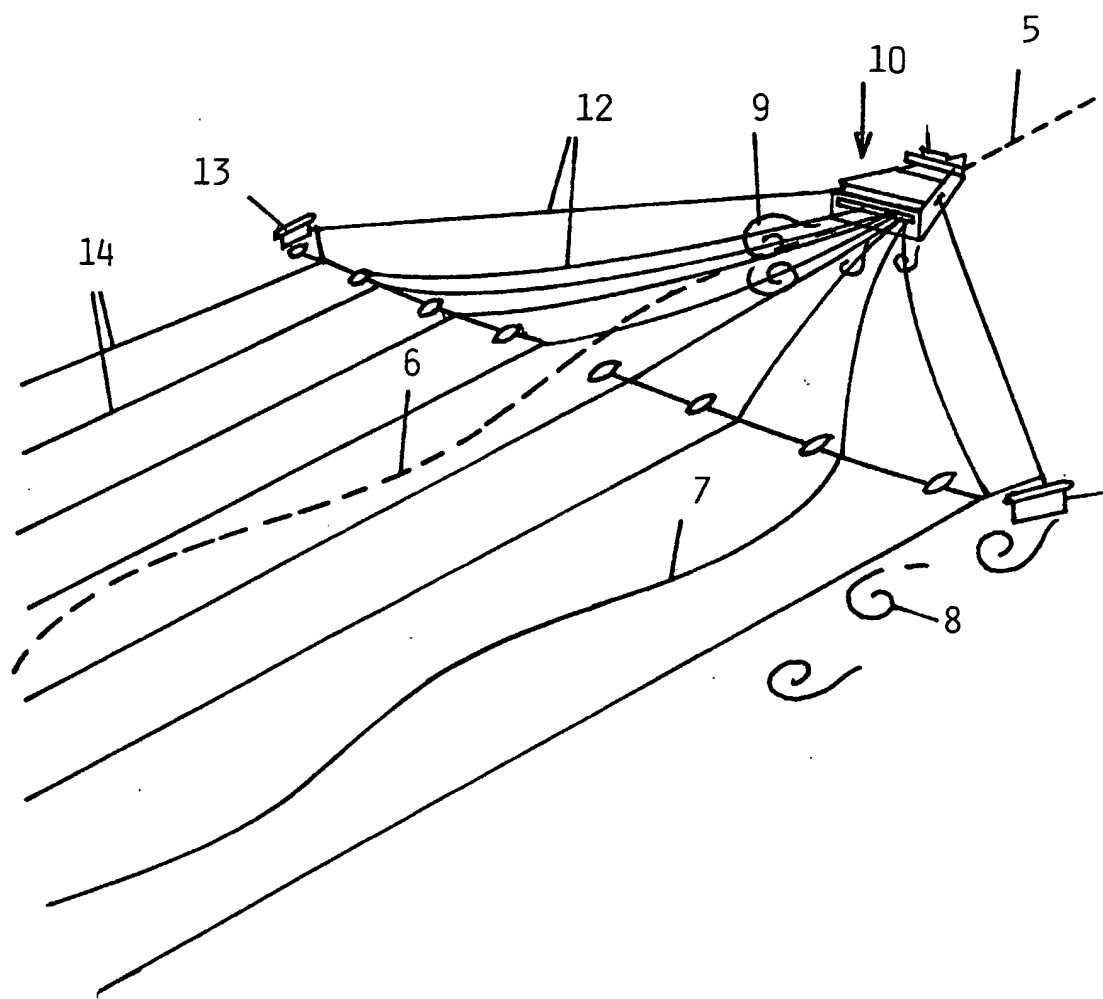


FIG. 2

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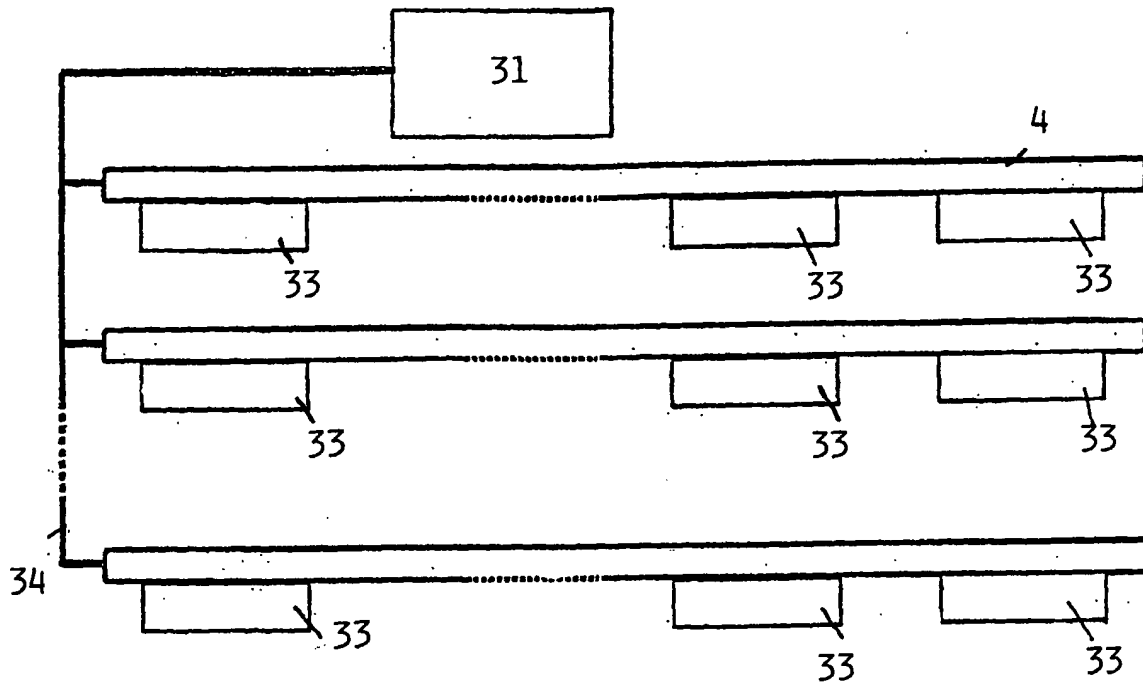


FIG. 3

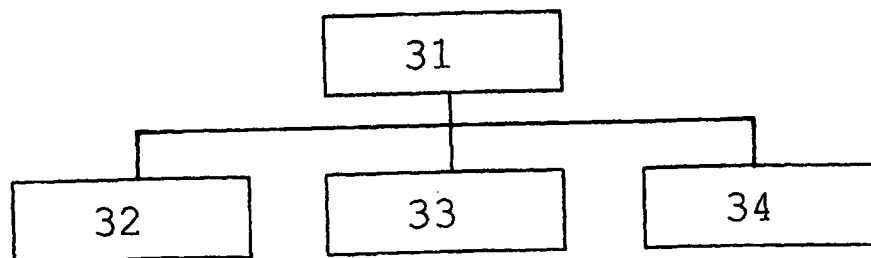


Fig. 4

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/NO 02/00032

## A. CLASSIFICATION OF SUBJECT MATTER

IPC7: G01V 1/38, B63B 21/66

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: G01V, B63B, G01S

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-INTERNAL, WPI DATA, PAJ, INSPEC

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5790472 A (RICKY L. WORKMAN ET AL), 4 August 1998 (04.08.98), column 2, line 66 - column 4, line 21 --	1-9
Y	GB 2047406 A (SHELL INTERNATIONAL RESEARCH MAATSCHAPPIJ BV), 26 November 1980 (26.11.80), page 4, line 36 - line 99 --	1-9
Y	US 4809005 A (CHARLES C. COUNSELMAN, III), 28 February 1989 (28.02.89), column 2, line 32 - line 68 --	1-9

☒ Further documents are listed in the continuation of Box C.☒ See patent family annex.

## \* Special categories of cited documents:

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier application or patent but published on or after the international filing date
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"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

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Box 5055, S-102 42 STOCKHOLM

Facsimile No. +46 8 666 02 86

Authorized officer

Gordana Ninkovic/mj

Telephone No. +46 8 782 25 00

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/NO 02/00032

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 8403153 A1 (A/S KONGSBERG VÅPENFABRIKK), 16 August 1984 (16.08.84), abstract  --	1-9
A	US 4581723 A (CARL H. SAVIT), 8 April 1986 (08.04.86), column 1, line 52 - column 2, line 16  --	1-9
A	US 4890568 A (GEORGE A. DOLENGOWSKI), 2 January 1990 (02.01.90), column 2, line 61 - column 3, line 42  --	1-9
A	GB 2087556 A (GOEPHYSICAL COMPANY OF NORWAY A.S.), 26 May 1982 (26.05.82), page 2, line 33 - line 87  --	1-9
A	US 4798156 A (JAN-AGE LANGELAND ET AL), 17 January 1989 (17.01.89), column 1, line 32 - column 2, line 6  -- -----	1-9



28/01/02

PCT/NO 02/00032

Form PCT/ISA/210 (patent family annex) (July 1998)

INTERNATIONAL SEARCH REPORT  
Information on patent family members

28/01/02

International application No.

PCT/NO 02/00032

Patent document cited in search report			Publication date	Patent family member(s)		Publication date
US	4809005	A	28/02/89	AU	568289 B	24/12/87
				AU	1064783 A	08/09/83
				AU	7842787 A	17/12/87
				CA	1226355 A	01/09/87
				CH	664442 A	29/02/88
				DE	3305478 A,C	15/09/83
				DK	85983 A	02/09/83
				DK	163197 B,C	03/02/92
				FI	82556 B,C	30/11/90
				FI	85916 B,C	28/02/92
				FI	830619 A	02/09/83
				FI	864103 A	10/10/86
				FR	2522413 A,B	02/09/83
				GB	2120489 A,B	30/11/83
				GB	8305051 D	00/00/00
				GB	8509093 D	00/00/00
				IT	1161095 B	11/03/87
				IT	8319766 D	00/00/00
				JP	2097560 C	02/10/96
				JP	2727306 B	11/03/98
				JP	7086529 B	20/09/95
				JP	8146111 A	07/06/96
				JP	58158570 A	20/09/83
				JP	62076475 A	08/04/87
				SE	460685 B,C	06/11/89
				SE	8301066 A	26/08/84
				SE	8802377 A	23/06/88
				US	4667203 A	19/05/87
				US	4860018 A	22/08/89
				US	4870422 A	26/09/89
				US	4894662 A	16/01/90
				US	5014066 A,B	07/05/91
				US	5194871 A	16/03/93
				US	5384574 A	24/01/95
				US	5619212 A	08/04/97
				US	5805200 A	08/09/98
				AU	602889 B	01/11/90
				AU	629728 B	08/10/92
				AU	638383 B	24/06/93
				AU	2609992 A	03/12/92
				AU	6994991 A	02/05/91
				AU	7078887 A	22/10/87
				BR	8701801 A	26/01/88
				CA	1291252 A	22/10/91
				DE	3789328 D,T	14/07/94
				EP	0242115 A,B	21/10/87
				NO	175917 B,C	19/09/94
				NO	871042 D	00/00/00
WO	8403153	A1	16/08/84	AU	2438584 A	30/08/84
				BR	8405066 A	26/12/84
				EP	0134804 A	27/03/85
				JP	60500383 T	22/03/85
				NO	830358 A	03/08/84
US	4581723	A	08/04/86	NONE		

28/01/02

PCT/NO 02/00032

Patent document cited in search report			Publication date	Patent family member(s)	Publication date
US	4890568	A	02/01/90	NONE	
<hr/>					
GB	2087556	A	26/05/82	AU 532808 B	13/10/83
				AU 7730981 A	20/05/82
				BR 8107275 A	03/08/82
				CA 1179761 A	18/12/84
				DE 3144196 A,C	09/06/82
				DK 159339 B,C	01/10/90
				DK 497081 A	13/05/82
				EG 15255 A	30/12/86
				ES 506388 A	01/03/83
				ES 8304320 A	16/05/83
				FR 2493995 A,B	14/05/82
				IE 51915 B	29/04/87
				IN 154225 A	06/10/84
				IT 1147507 B	19/11/86
				IT 8184145 D	00/00/00
				JP 57110975 A	10/07/82
				MX 156784 A	04/10/88
				NL 185369 B,C	16/10/89
				NL 8105012 A	01/06/82
				NO 147655 B,C	07/02/83
				NO 803400 A	13/05/82
				NZ 198936 A	28/09/84
				OA 6943 A	31/07/83
				PH 20108 A	29/09/86
				US 4506352 A	19/03/85
				ZA 8107136 A	29/09/82
<hr/>					
US	4798156	A	17/01/89	CA 1300436 A	12/05/92
				DE 3723393 A	28/01/88
				DK 164609 B,C	20/07/92
				DK 371487 A	18/01/88
				FR 2601642 A,B	22/01/88
				GB 2193942 A,B	24/02/88
				GB 8716864 D	00/00/00
				NL 193168 B,C	01/09/98
				NL 8701687 A	16/02/88
				NO 160984 B,C	13/03/89
				NO 862885 A	18/01/88
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